

Convection parameterization for the NCEP Weather and Climate model

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With help from

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Climate modeler's interest in convection parameterization

Maintenance of the Hadley Cell, the Walker Cell,
the prediction of ENSO, and climate response to increasing CO₂

Removal of model biases

Double ITCZ

Weather in the climate models

Mid-latitude disturbances are realistic

Tropical variabilities are too weak for
synoptic scales, MJO and ENSO

Tropical cyclogenesis investigated through nested mesoscale
models

Recent work using cloud resolving models to simulate the climate

Indications are that the MJOs get stronger and the models can generate
tropical storms

Weather modeler's interest in convection parameterization

Tropical storm tracks

Tropical storm genesis

Summer precipitation over land

Predictions of meso-scale convective systems

In recent years, MJO and ENSO as well

At NCEP, the global weather model is used for weather and climate

**Parameterized convection can do the job
if
we continue to work on the problem**

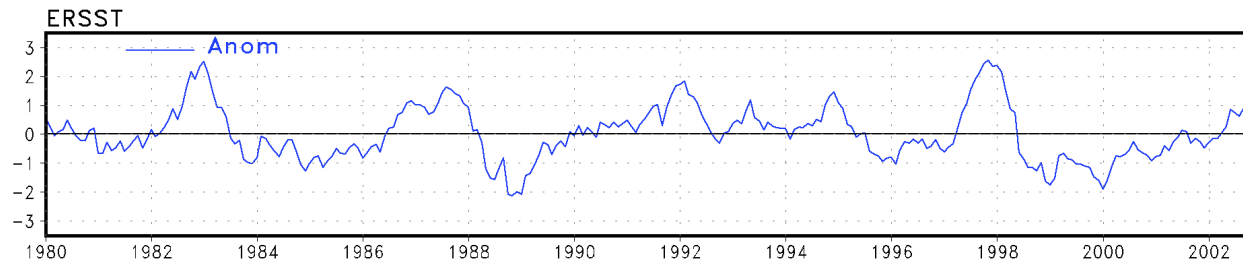
CFS (coupled) Simulations

64 Level (0.2 hPa) vs 28 Level (2.0 hPa) Atm.

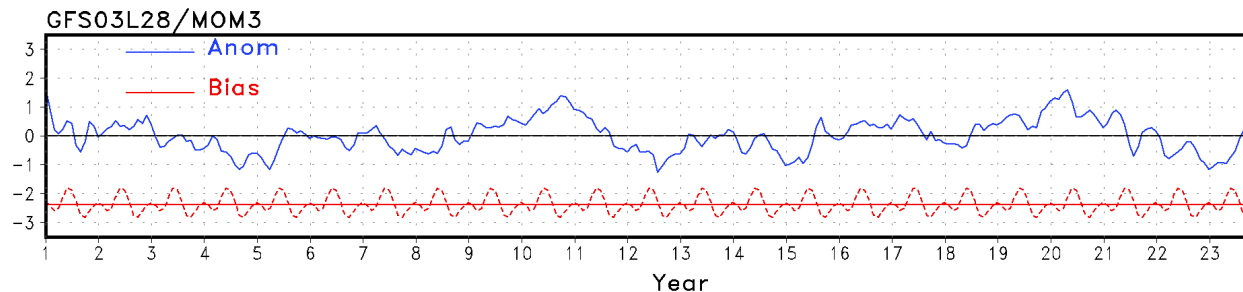
ENSO SST cycles

Nino 3.4 SST Anomalies

Observed

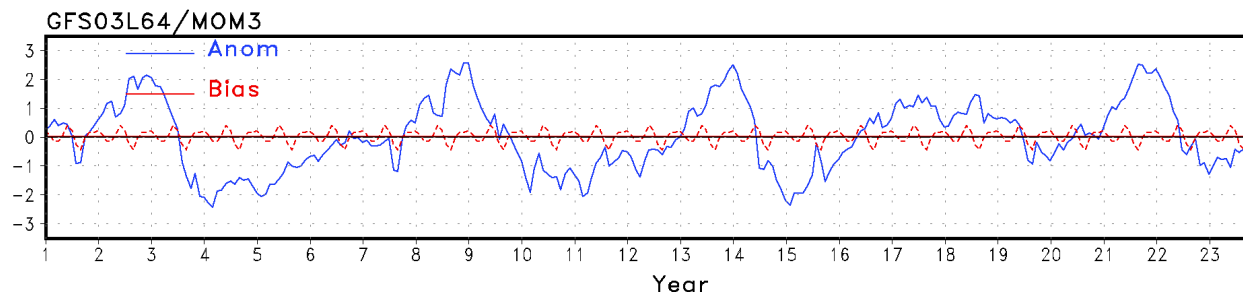


28 Level Atm

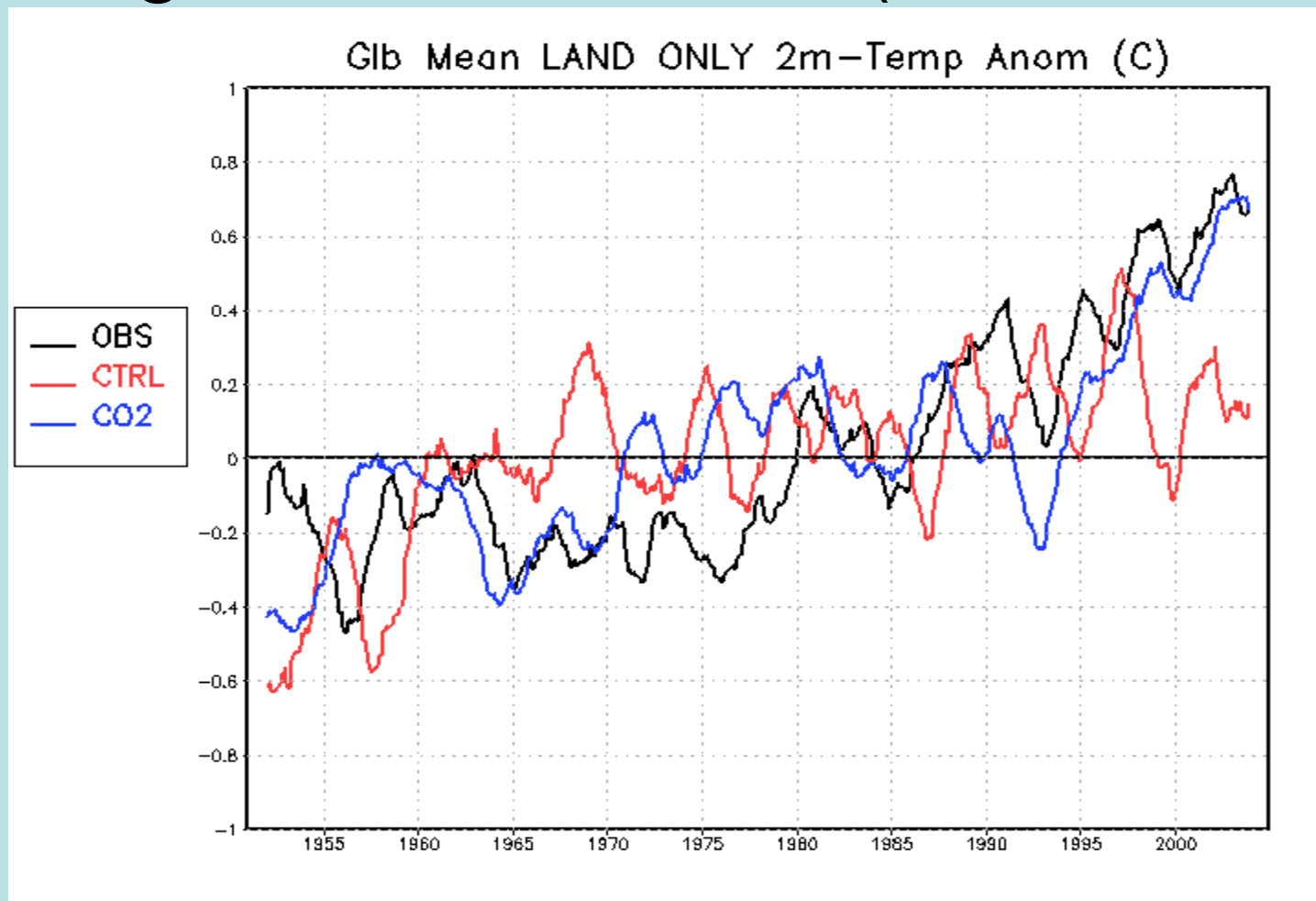


Coupled
Red: monthly bias

64 Level Atm



Testing with CMIP Runs (variable CO2)



OBS is CPC Analysis (Fan and van den Dool, 2008)

CTRL is CMIP run with 1988 CO₂ settings (no variations in CO₂, current operations)

CO₂ run is the ensemble mean of 3 NCEP CFS runs in CMIP mode

– realistic CO₂ and aerosols in both troposphere and stratosphere

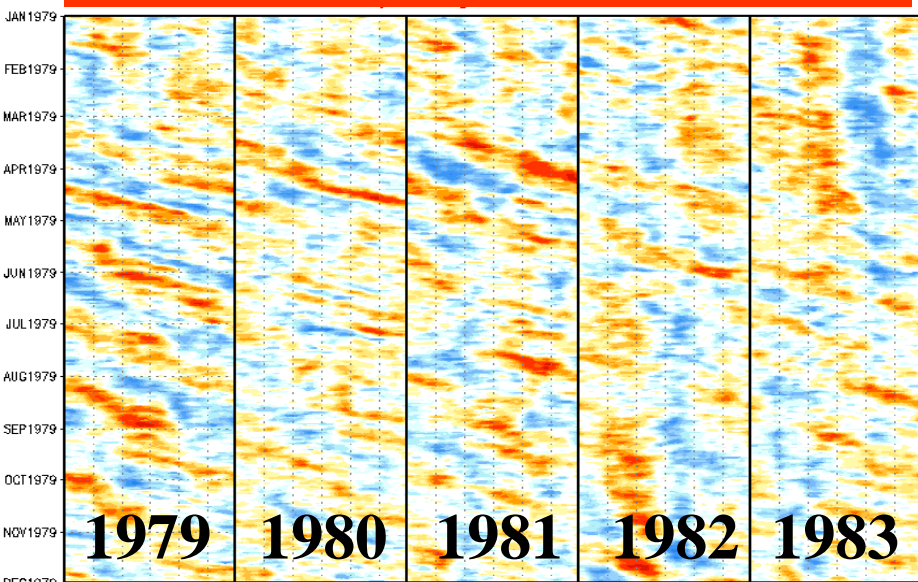
Processing: 25-month running mean applied to the time series of anomalies (deviations from their own climatologies)

200 hPa Divergence

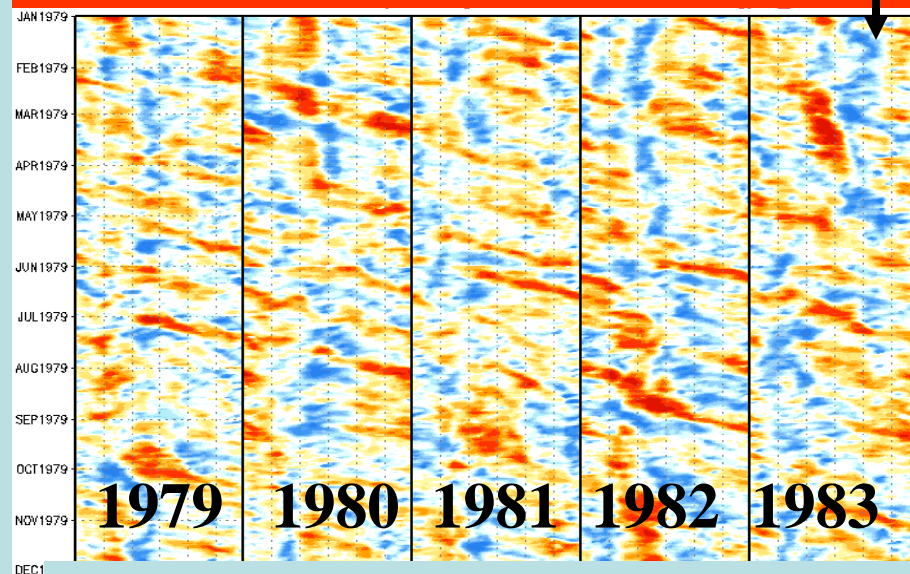
MJO Events

ENSO Event

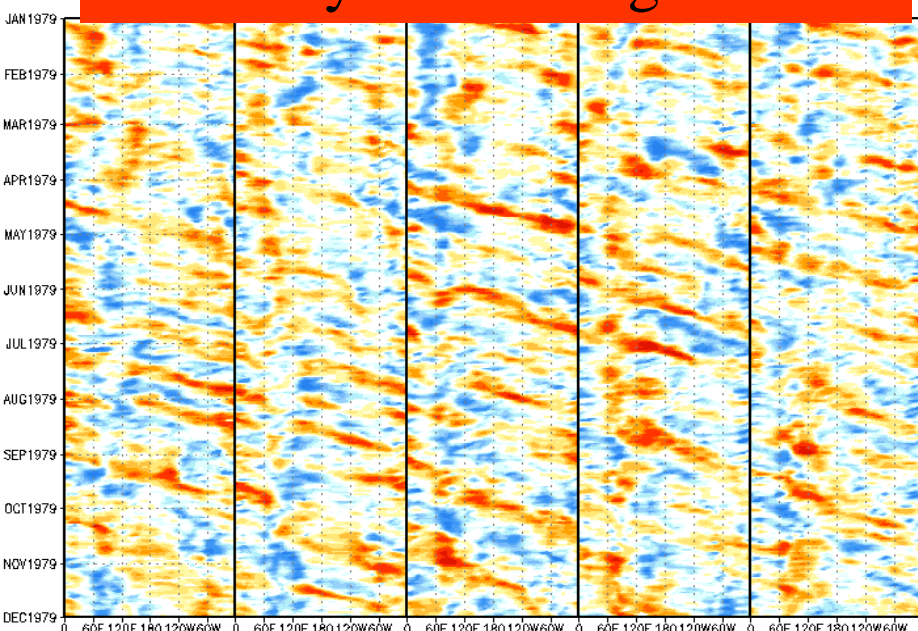
Observed



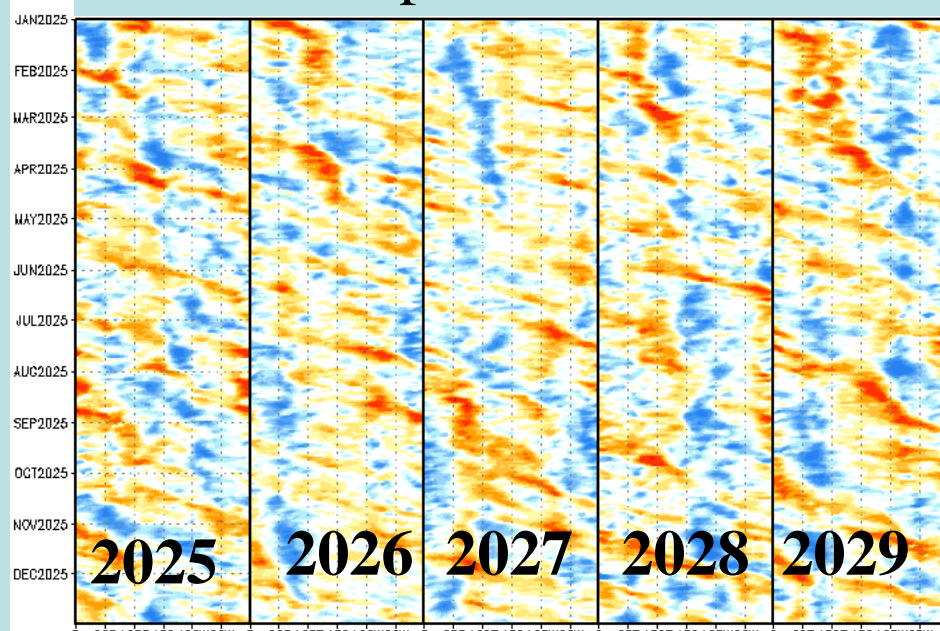
“AMIP” (forced by monthly SST)



Forced by Climatological SST



Coupled 64 Level

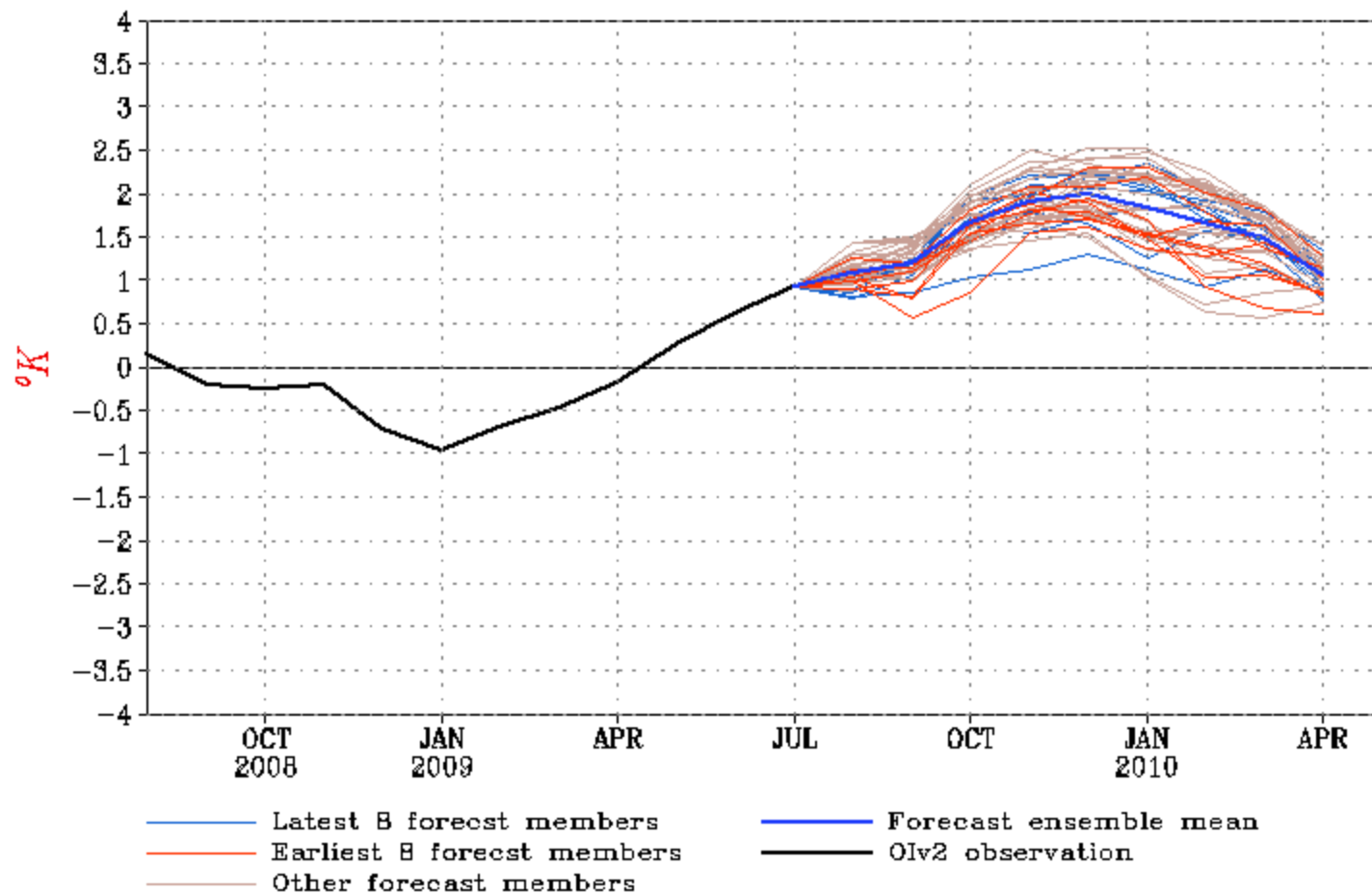




NWS/NCEP

Last update: Wed Jul 29 2009
Initial conditions: 16Jul2009-25Jul2009

PDF correction: Forecast *Nino3.4* SST anomalies from CFS

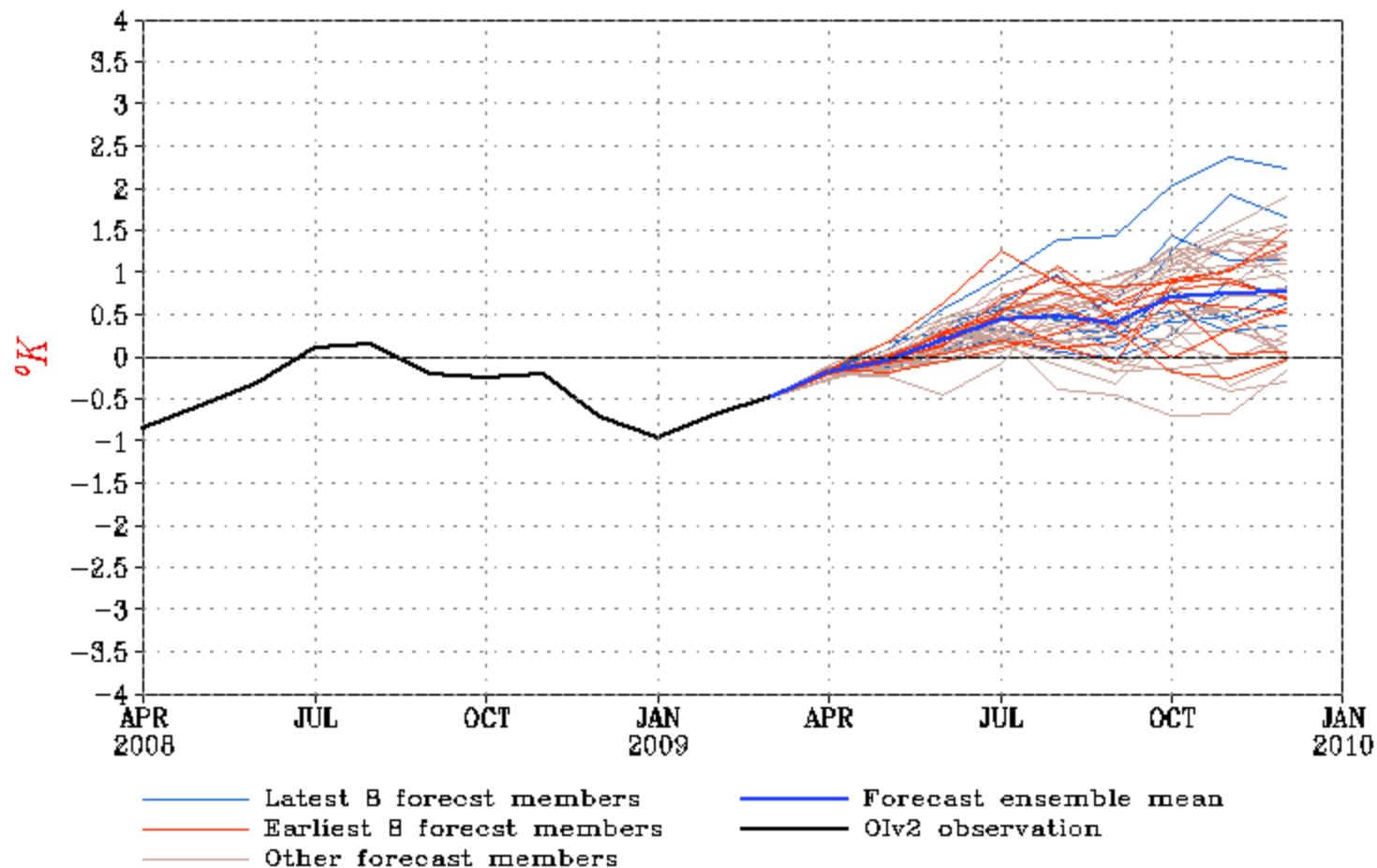




NWS/NCEP

Last update: Mon Apr 13 2009
Initial conditions: 2Apr2009–11Apr2009

PDF correction: Forecast *Nino3.4* SST anomalies from CFS



What Needs to be Done?

- Parameterization of convection is still needed for the next 5-10 years
- Continue to develop and improve the physical basis for coded algorithms determining current performance
 - Improvements need to perform as well (or better) for both weather and climate models
 - Improvement areas
 - Trigger
 - Closure
 - Cloud momentum mixing
 - Cloud model

Trigger function

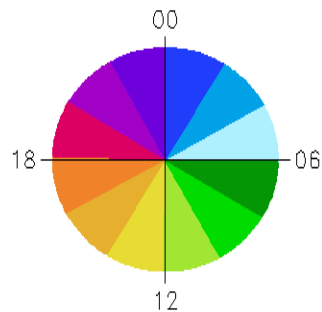
- Most mass-flux schemes use closure as trigger ... Whenever the column is unstable 'enough', convection starts
 - Modifications to delay onset mostly use environmental conditions such as RH
- Meso-scale modelers look at parcel buoyancy when lifting a parcel through inversion

Trigger in the GFS

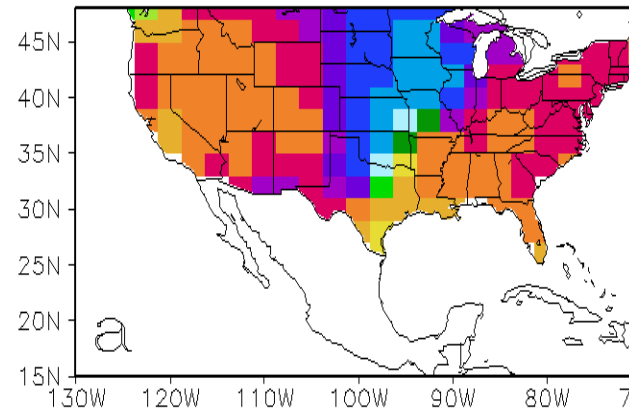
- GFS uses the parcel concept to check for level of free convection
 - Simplified trigger requires lifted parcel to have level of free convection within 150 hPa
 - Often delays the onset of convection

Phase (local time) of Maximum Precipitation (24-hour cycle)

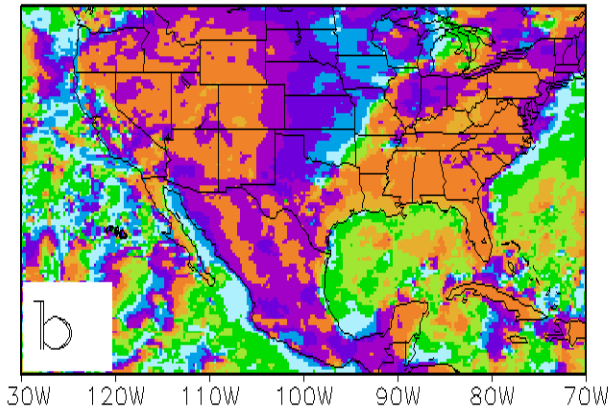
Diurnal Phase
(LST)



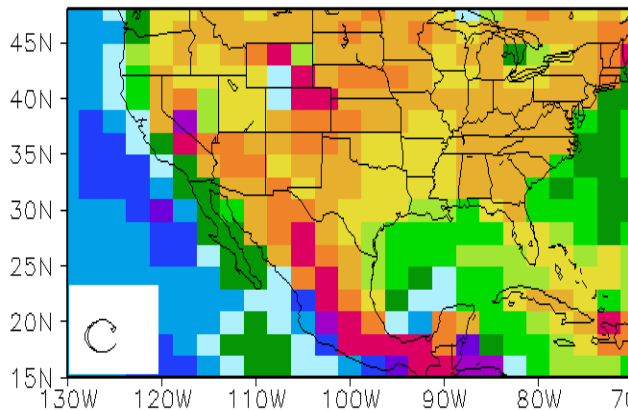
HPD



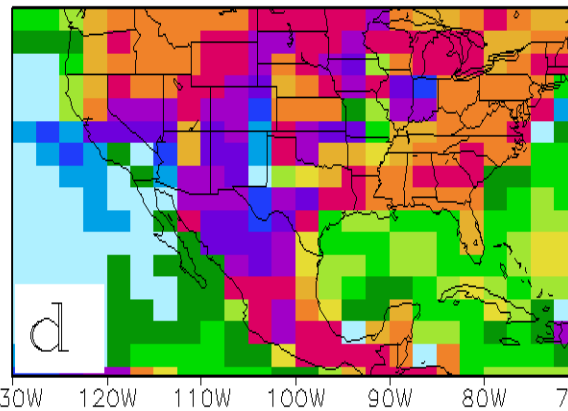
CMORPH



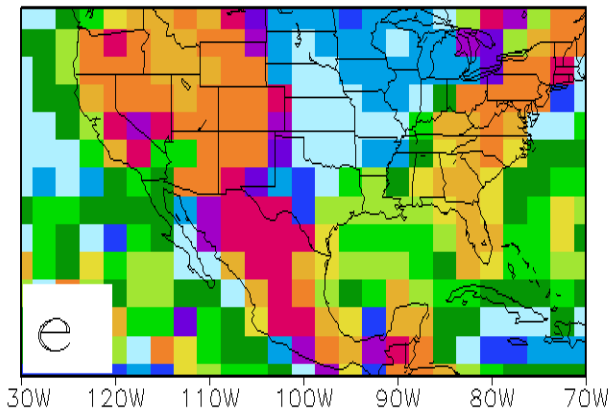
NASA 2 DEG



GFDL 2 DEG



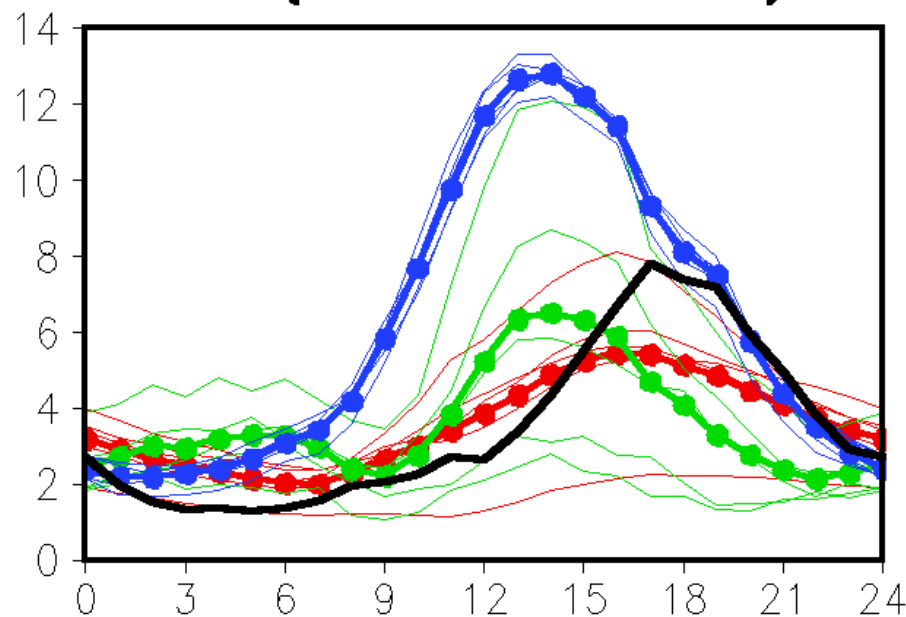
NCEP T62



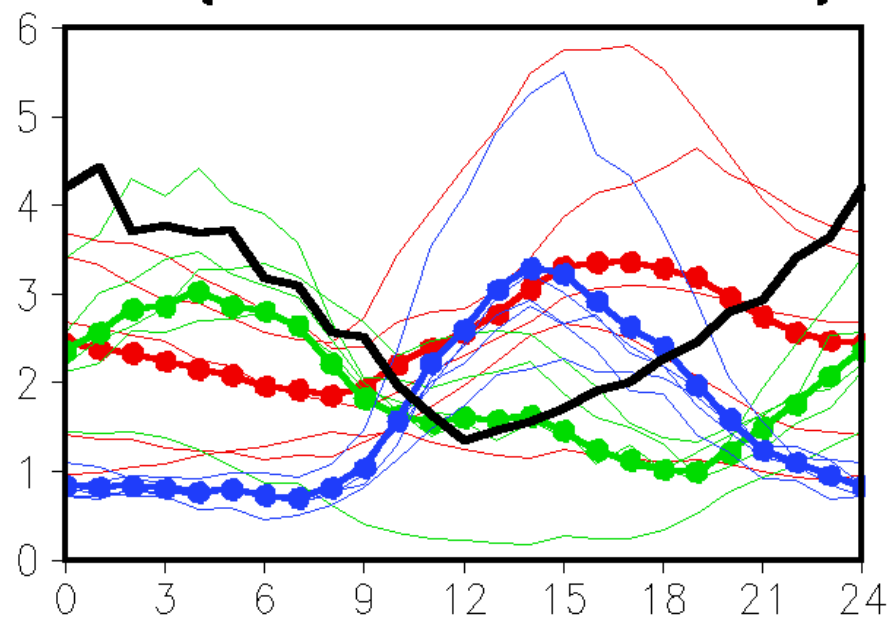
Five-member ensembles driven by Climatological SST forcing (1983-2002 avg)

Diurnal Cycle of Rainfall – Ensemble Mean and Spread

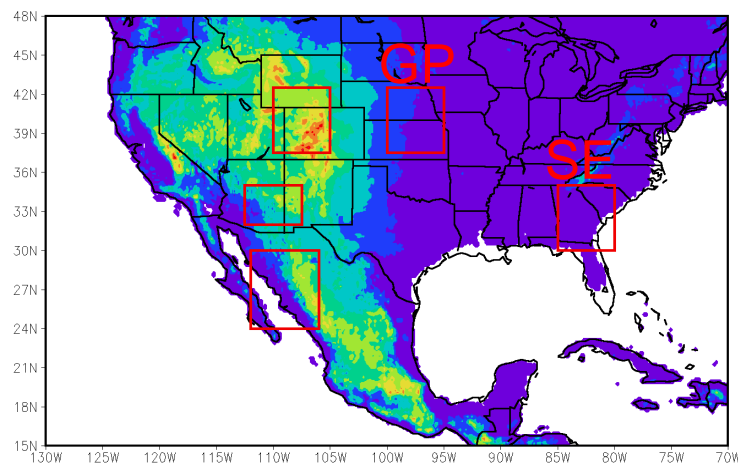
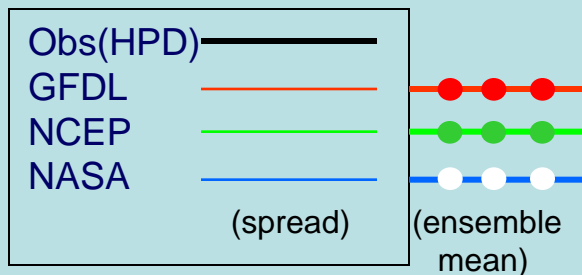
SE (85–80W,30–35N)



GP (100–95W,37.5–42.5N)



LST



CTRL: Control run with the standard SAS scheme

EXP1: Same as CTRL but with the fixed critical CWF in time
(independent to the vertical motion)

EXP2: Same as CTRL but with the fixed relaxation time scale
(30 minutes)

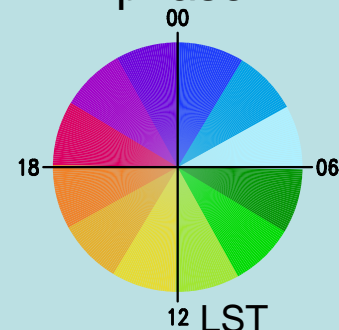
EXP3: Same as CTRL but the convection starting level is
always fixed at the first model level

EXP4: Same as CTRL but the LFC must be located within 500 hPa depth
of the convection starting level

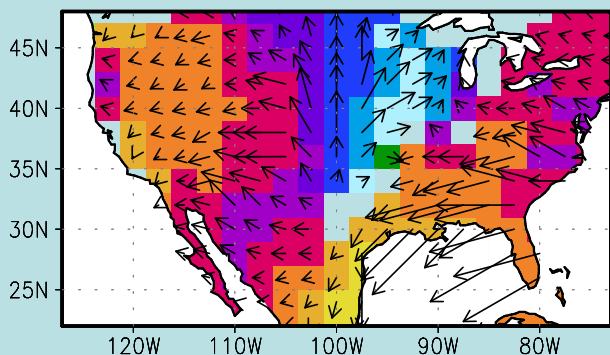
amplitude

→
5 mm/day

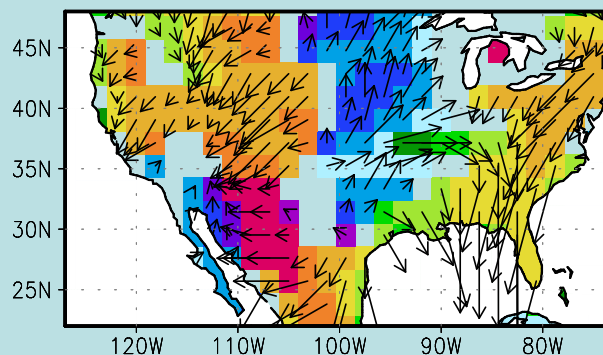
phase



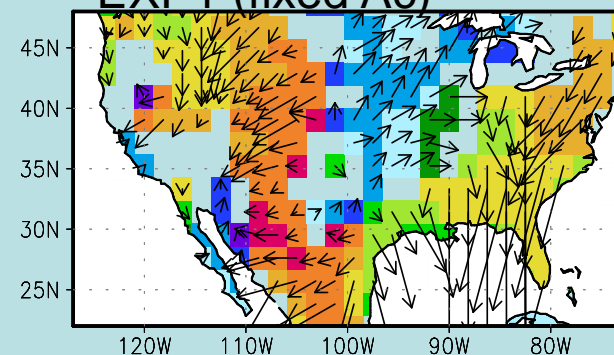
HPD(OBS)



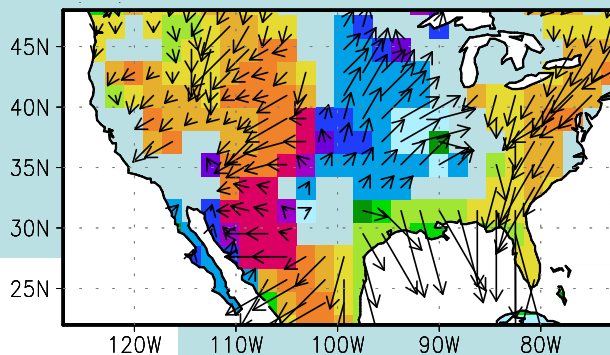
CTRL



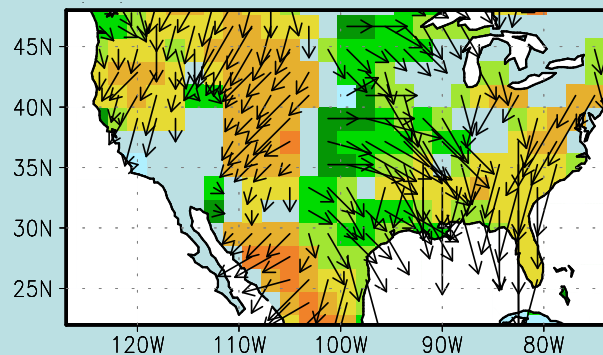
EXP1 (fixed Ac)



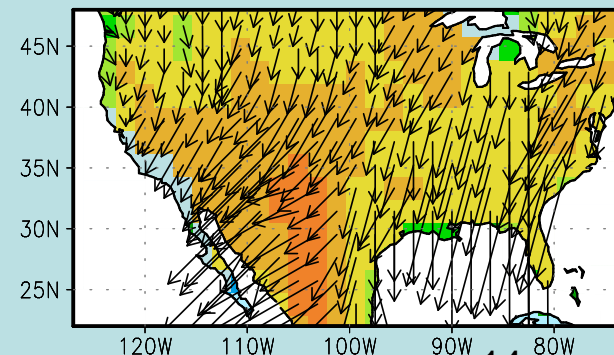
EXP2 (fixed t)



EXP3 (starting level)

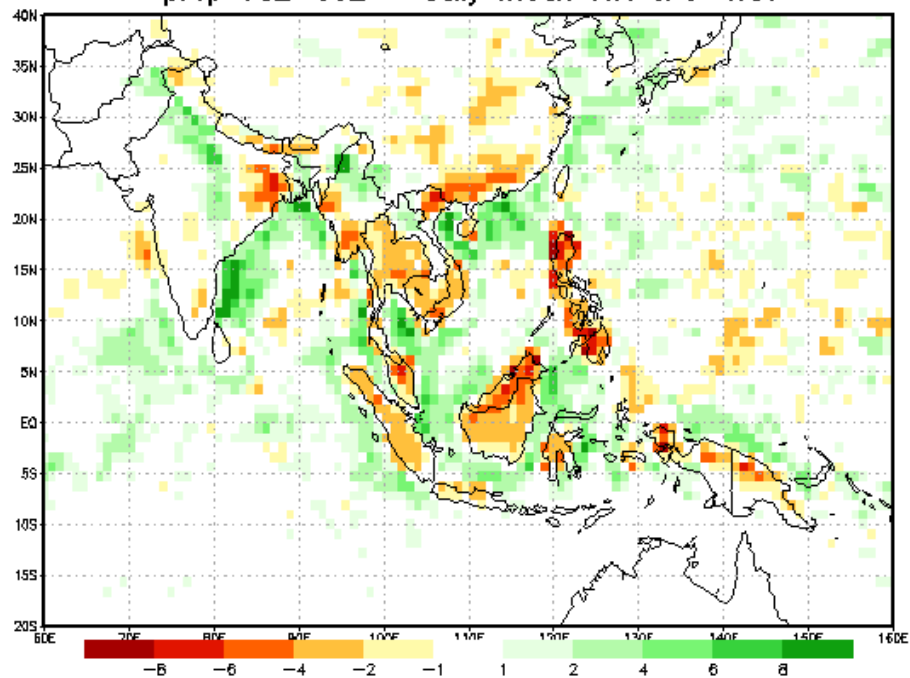


EXP4 (lifting depth trigger)

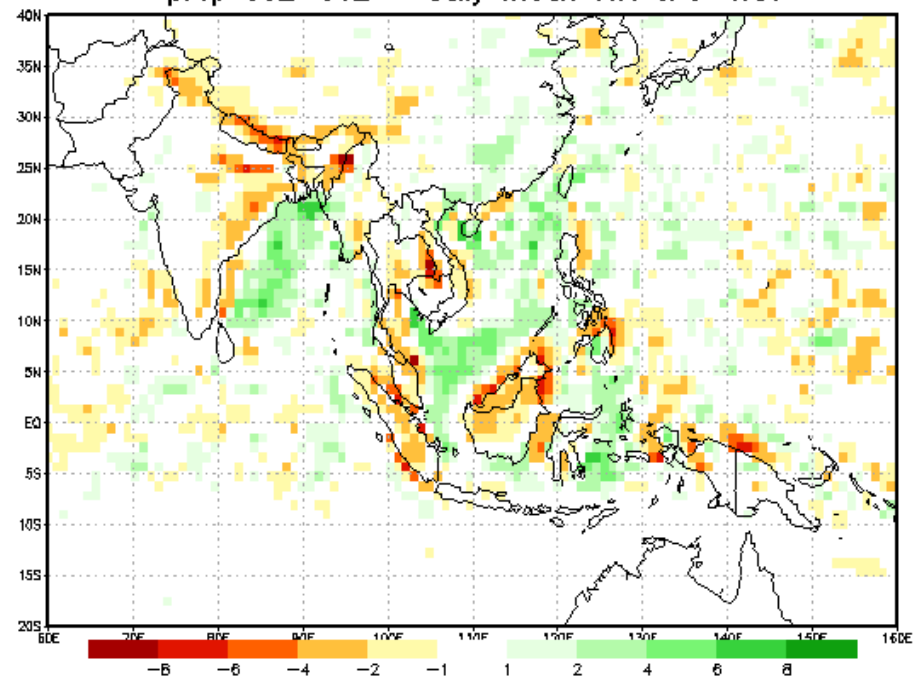


14

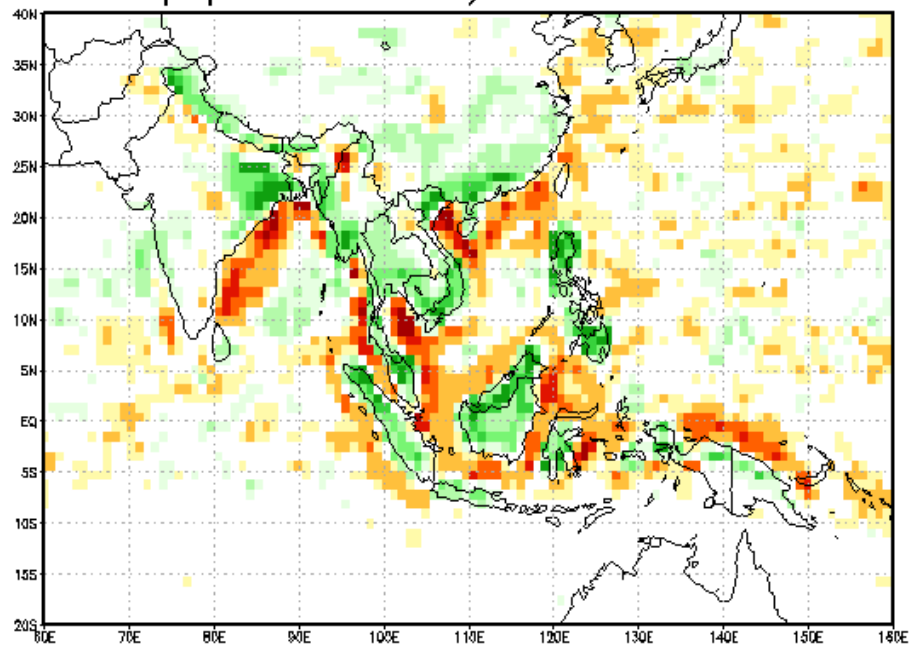
precip 18Z-00Z - daily mean JJA CFS-test



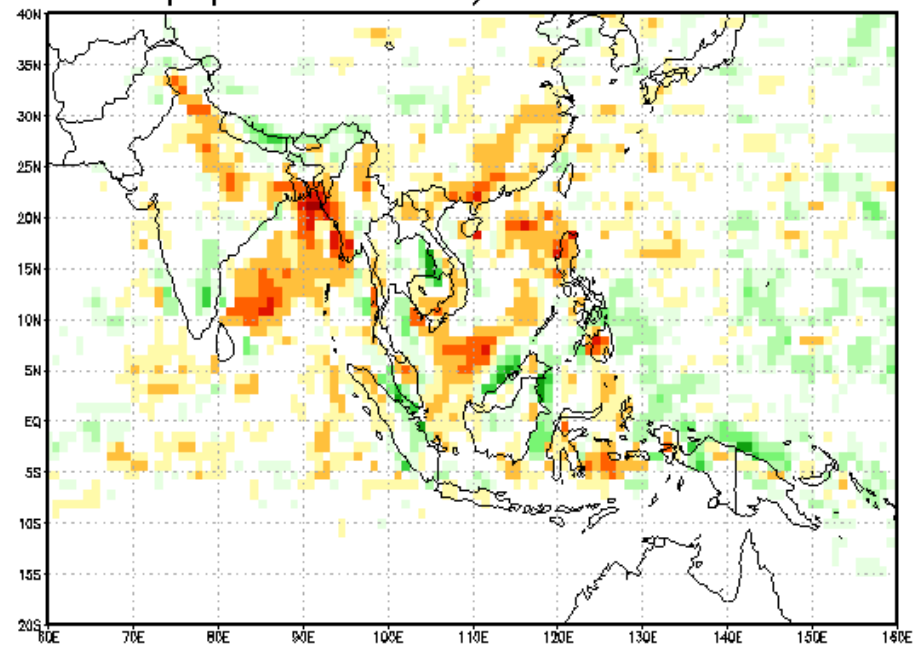
precip 00Z-06Z - daily mean JJA CFS-test



precip 06Z-12Z - daily mean JJA CFS-test



precip 12Z-18Z - daily mean JJA CFS-test



Closure

- Traditional closure for climate models
 - Rate of adjustment of the column CAPE (or cloud work function) to the final state
- For meso-scale models
 - Final state has convective instability eliminated **(CAPE elimination)**
 - **Moist adiabat** (after accounting for liquid and/or frozen water)
- For GFS closure
 - Approaches CAPE elimination when the atmospheric state is 'disturbed'
 - Modifies 'climate CAPE' with the ambient vertical motion

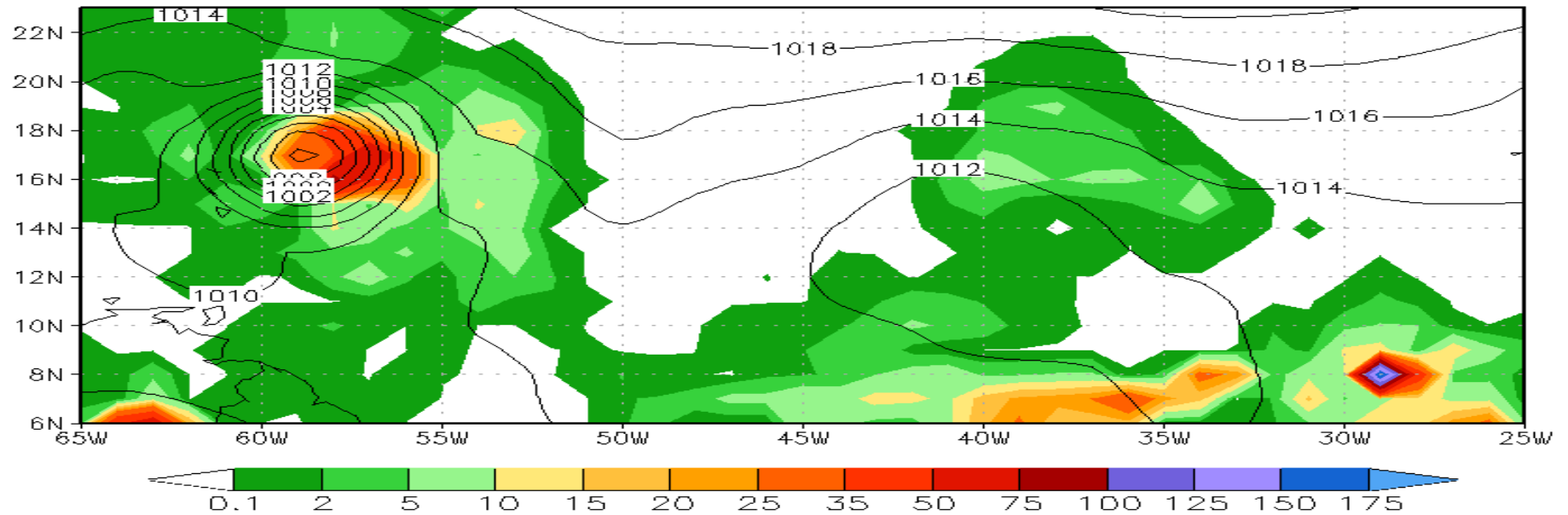
Cumulus Momentum Mixing (CMM)

- Has a remarkable effect on tropical storm genesis
 - Without CMM
 - Most of the tropical disturbances develop vorticity centers due mostly to grid-scale heating.
 - Grid-scale “resolved” convection
 - Too many disturbances
 - With CMM
 - Parameterized convective heating is smaller
 - Most important, vortex development is restricted only to the ‘real’ storms

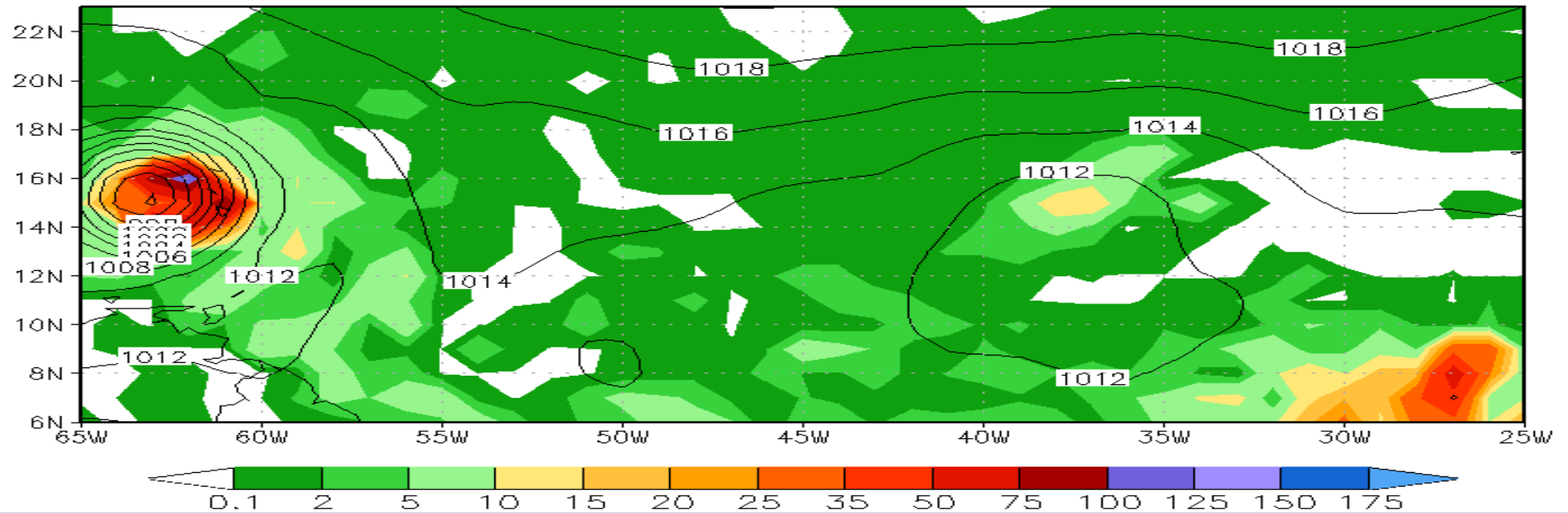
Simple cloud model in SAS

- The cloud model in the A-S scheme is a simple one. We should be able to add better physics in it.
- Currently, there is no cloud water generated other than at the detrainment level, so convective cloud needed in radiation is either made up or missing.
- Cloud top level is a new issue we are studying.
- A new package of deep and shallow convection is under testing.

Tprp FT=114-120 12Z13Aug2007 CTL



Tprp FT=114-120 12Z13Aug2007 s38he+ql



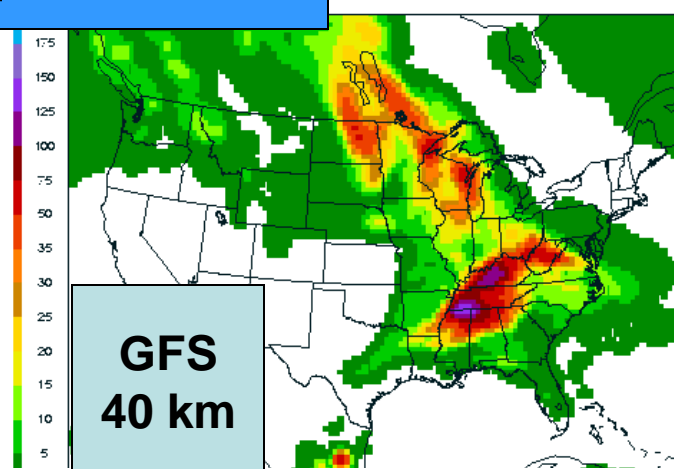
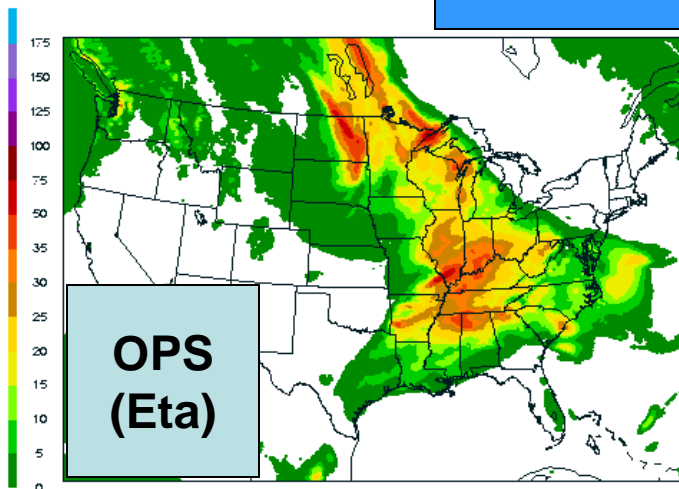
Mesoscale modeling

- How does parameterized convection (and for that matter turbulence) work when the resolution goes from 40 km to 4 km?
 - The “convergence” problem for convective parameterization (Arakawa)
 - With the GFS trigger
 - Air column in disturbed regions becomes very moist
 - CAPE is reduced
 - i.e. moist adiabat is approached
 - Parameterized convection plays a diminishing role
 - Grid-scale convection “takes over”
- Convective momentum mixing continues to exert influence on the intensity of the tropical storms

PRECIP (mm)
24h accum
VALID 12Z 31 MAY 2004

24 h Forecasts 12 UTC 31 May 2004

GFS
24-H FCST
40.6 KM LMB CON GRD

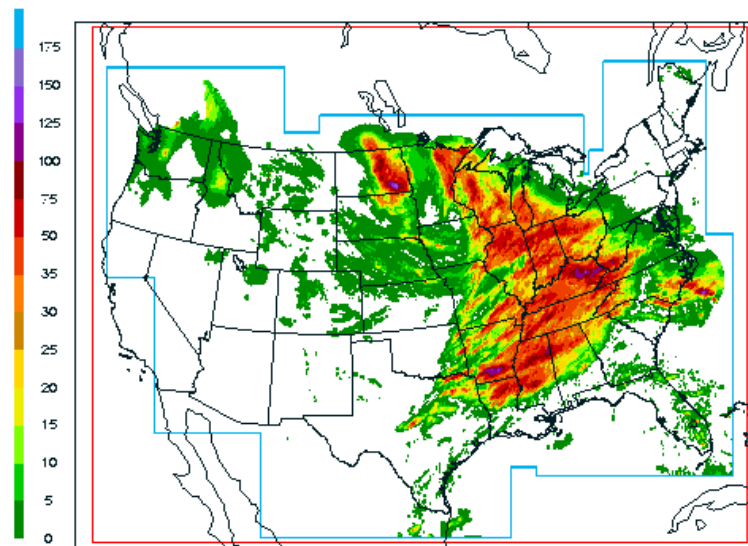
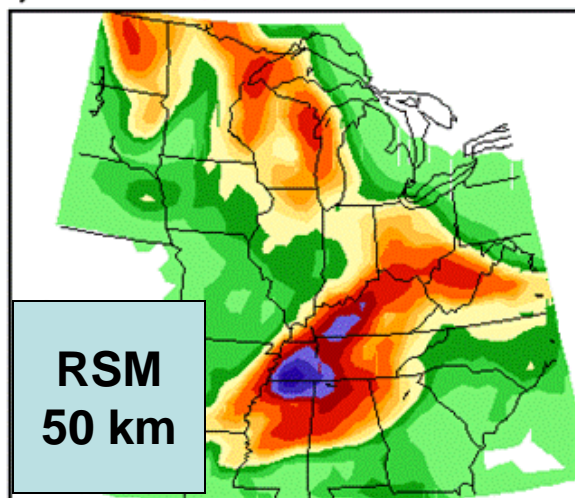


PRECIP (mm)
24h accum
VALID 12Z 31 MAY 2004

Observed Precip

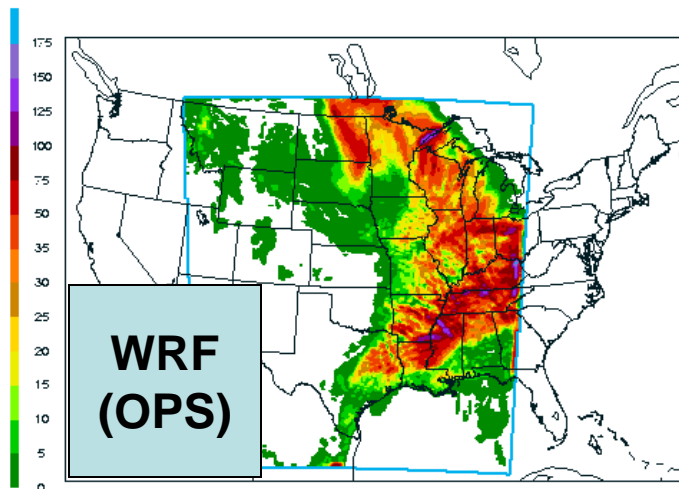
Stage IV (III MOS)
4.8 KM POL STR GRD

Tprp(mm/24hr) 50km V2004053112 RSM-SAS f24



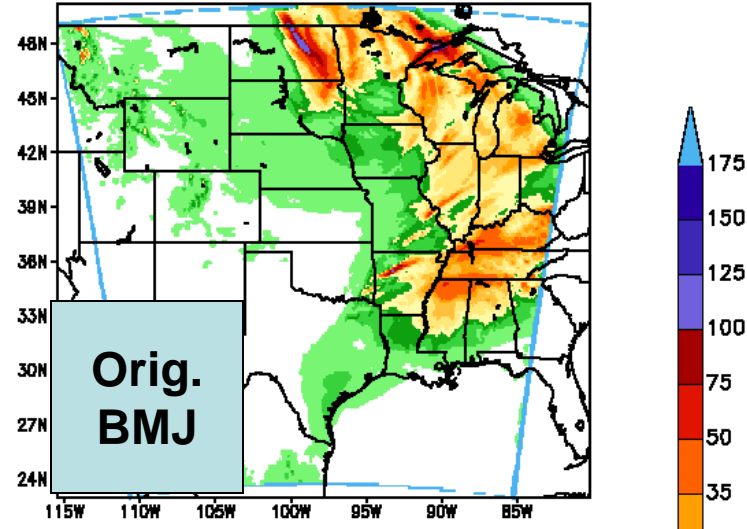
PRECIP (mm)
24h accum
VALID 12Z 31 MAY 2004

WRFCENT
24-H FCST
12.2 KM LMB CON GRD



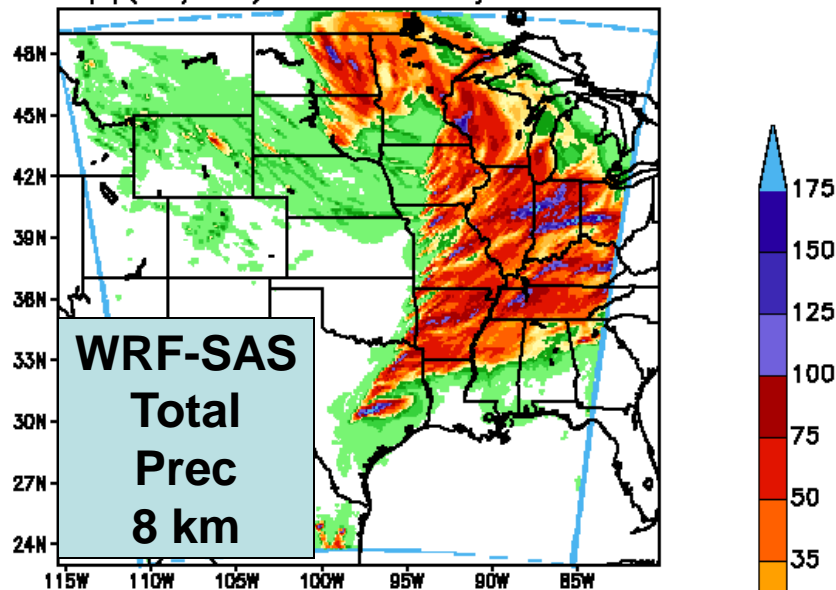
BMJ CONV 24-HR FCST 4-KM

Tprp(mm/24hr) Valid 12Z 31 May04 WRF 4km



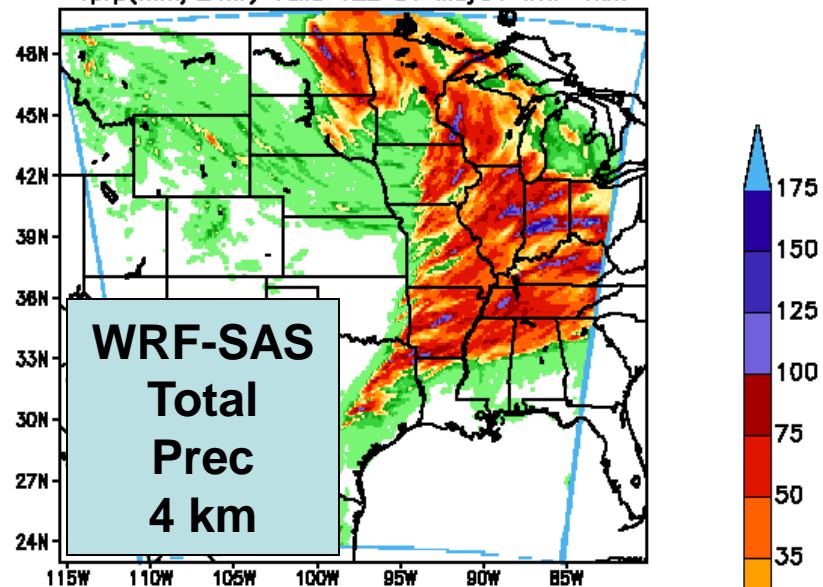
SAS CONV 24-HR FCST 8-KM

Tprp(mm/24hr) Valid 12Z 31 May04 WRF 8km



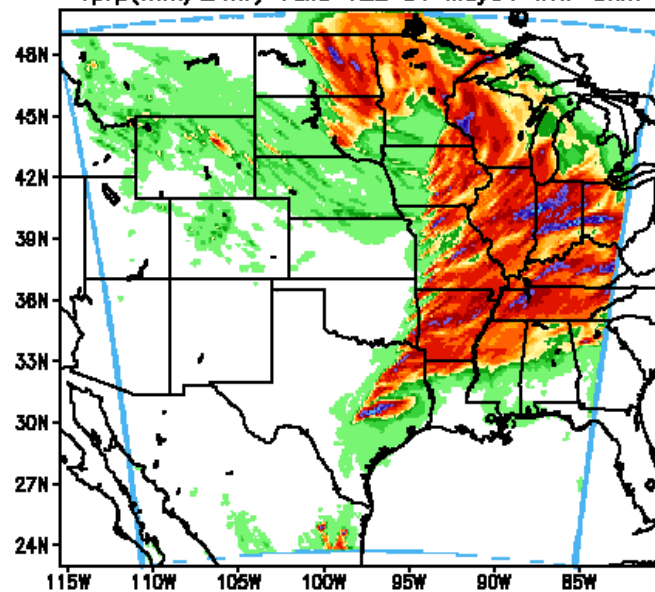
SAS CONV 24-HR FCST 4-KM

Tprp(mm/24hr) Valid 12Z 31 May04 WRF 4km



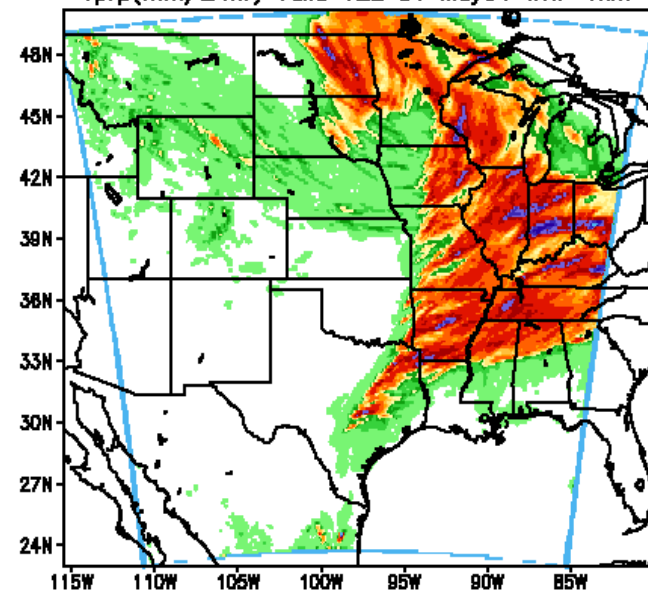
SAS CONV 24-HR FCST 8-KM

Tprp(mm/24hr) Valid 12Z 31 May04 WRF 8km

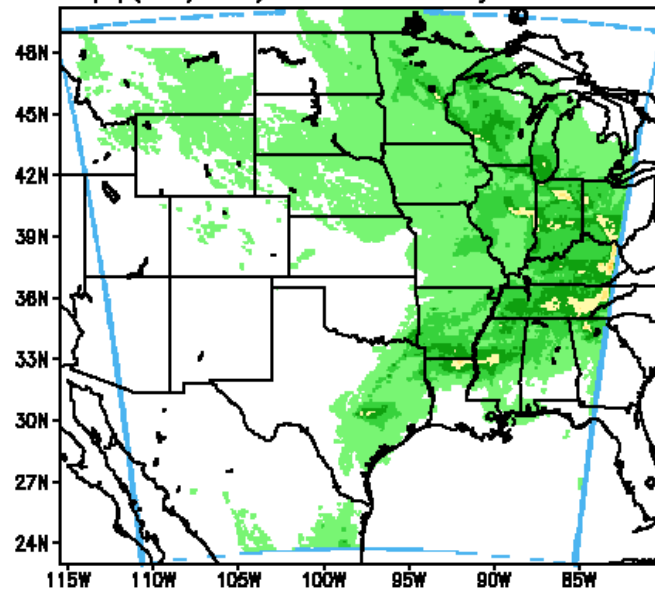


SAS CONV 24-HR FCST 4-KM

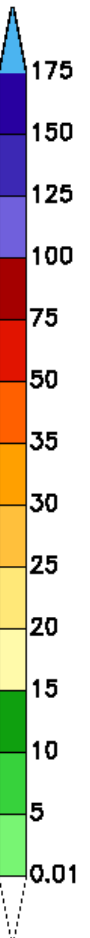
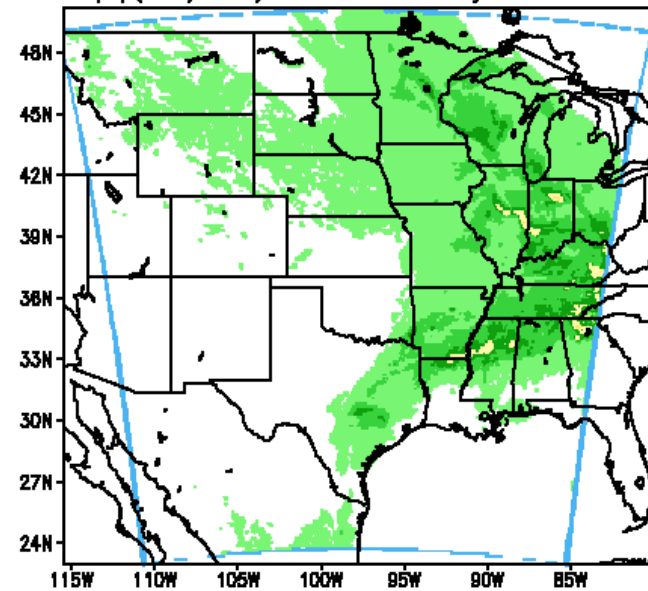
Tprp(mm/24hr) Valid 12Z 31 May04 WRF 4km



Cprp(mm/24hr) Valid 12Z 31 May04 WRF 8km



Cprp(mm/24hr) Valid 12Z 31 May04 WRF 4km



Summary

- Contribution of parameterized convection important until sub-4 km resolution is reached
- To continue to improve NCEP's real time applications, convective parameterization will continue to be developed
- Climate models can benefit from better parameterized convection in next 5-10 years
- Improvement areas
 - Convective trigger (+PBL)
 - Convective momentum transport
 - Refining physical basis for closure
 - Better cloud model within the convection scheme
 - A mass flux based shallow convection scheme
- Approach must be physically-based
 - CRMs can be useful for specific problems (e.g. CMM)
 - To run at the many resolutions required, the scheme has to be physically based